MENO
Managed Ecosystems of Networked Objects
- easy and secure cloud-based sensor data processing -

Ingrid Moerman, Jeroen Hoebeke

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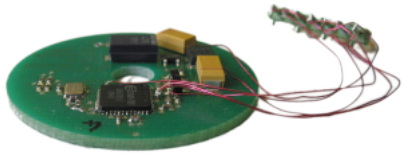
Internet evolution - sensors

- Sensors will become a cornerstone of the Future Internet
  - Collect physical world information
  - Inject it in the virtual world for aggregation/processing
  - Act upon the physical world
  - Enable many novel Internet services

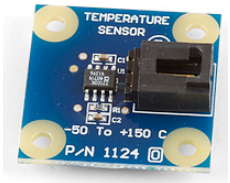
LOGISTICS

TRANSPORTATION

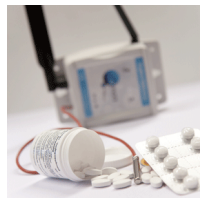
ENVIRONMENT MONITORING



COMMERCIAL



SECURITY AND SURVEILLANCE



SMART BUILDINGS

MILITARY

MEDICAL/BIOMEDICAL

HEALTHCARE

INDUSTRIAL

CONTROL AND AUTOMATION

TRAFFIC MANAGEMENT

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Internet evolution – cloud computing

- Increasing interest in cloud computing
  - Paradigm of computing to offer dynamically scalable and often virtualized resources as a service over the Internet
  - On demand provisioning of resources: data storage, computing power, software, information
  - Without requiring technical expertise from users

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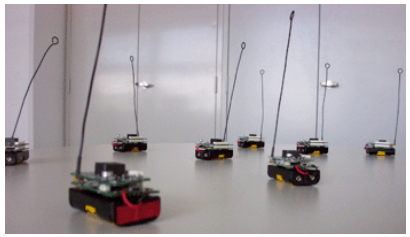
The missing link?



# of SENSOR NETWORKS

- Huge amounts of data
- Requiring aggregation, storage, processing, reasoning

INTERNET

USER

- Limited processing power and storage facilities

# of CLOUD SERVICES

- Scalable processing power and storage facilities

INTERESTED PARTIES

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Use case 1/3

- **Transport scenario**
  - Monitoring of trucks of a transport company equipped with different sensors (camera, temperature, pollution, driving behavior, location, road conditions…)
  - Storage and processing of huge amounts of sensor data in cloud (creation of processing chains)
  - Enrichment of data with external information
  - Making data available to third parties (customers, government, insurance company…)

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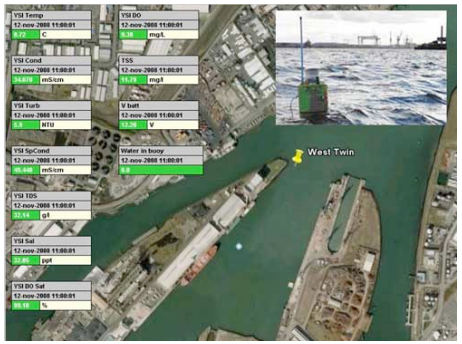
Use case 2/3

- **Site monitoring**
  - Large company monitoring several sites (toxic waste, gasses, smoke, camera…)
  - Storage and processing of huge amounts of sensor data from distributed locations in cloud
  - Making data available to third parties (government, insurance company, people living nearby…)



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Use case 3/3

- **Home scenario**
  - Home equipped with sensor nodes (HVAC, fire detection, cameras, passive monitoring…)
  - Storage and processing by cloud resources
  - Availability to third parties (fire brigade, caregivers…)
  - Direct sensor data access from wherever you are

Challenges 1/3

- Sensor nodes/networks are seen as an add-on to the Internet, being connected via dedicated gateways
  - ⊕ Central point of communication, configuration, access control
  - ⊖ Disadvantages (1)
    - Complexity for application developers
      - Implement vendor-specific API to access sensor data
      - Complex with increasing number of vendors, sensors, locations…
      - Difficult to create complex processing chains
    - Protocol translation between sensor and IP world
      - Translation functionality for every sensor application
      - New sensors ➔ gateway upgrade
      - Intelligence for acting on raw sensor data often in gateway

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Challenges 2/3

- Sensor nodes/networks are seen as an add-on to Internet, being connected via dedicated gateways
  - ⛔ Disadvantages (2)
    - Communication focus
      - Focus on internal (within the sensor network) communication + web service to publish data
      - not on communication between gateway and interested parties
    - Vendor lock-in
      - Despite standards, vendors often modify them
      - Sensors from one vendor require gateway from that vendor
      - Limits customer flexibility: different vendors ➔ different gateways
      - Difficult for start-ups to enter sensor market
    - Sensor node distribution and mobility
      - Different sites: different gateways + awareness of this by applications requiring the sensor data (connectivity)
      - When bound to gateway: difficult to migrate

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Challenges 3/3

Secure, trusted, easy and direct processing and storage of sensor data (different sensors, locations, heterogeneity, mobility…) by one or multiple cloud services and over heterogeneous (wireless) networks is difficult and complex due to these disadvantages!

High complexity for implementing use cases, since no generic approach possible.

Future Internet PPP vision: innovative Internet-enabled smart infrastructures and processes require at least to capitalise on sensor networks, cloud like service infrastructures, wireless capabilities

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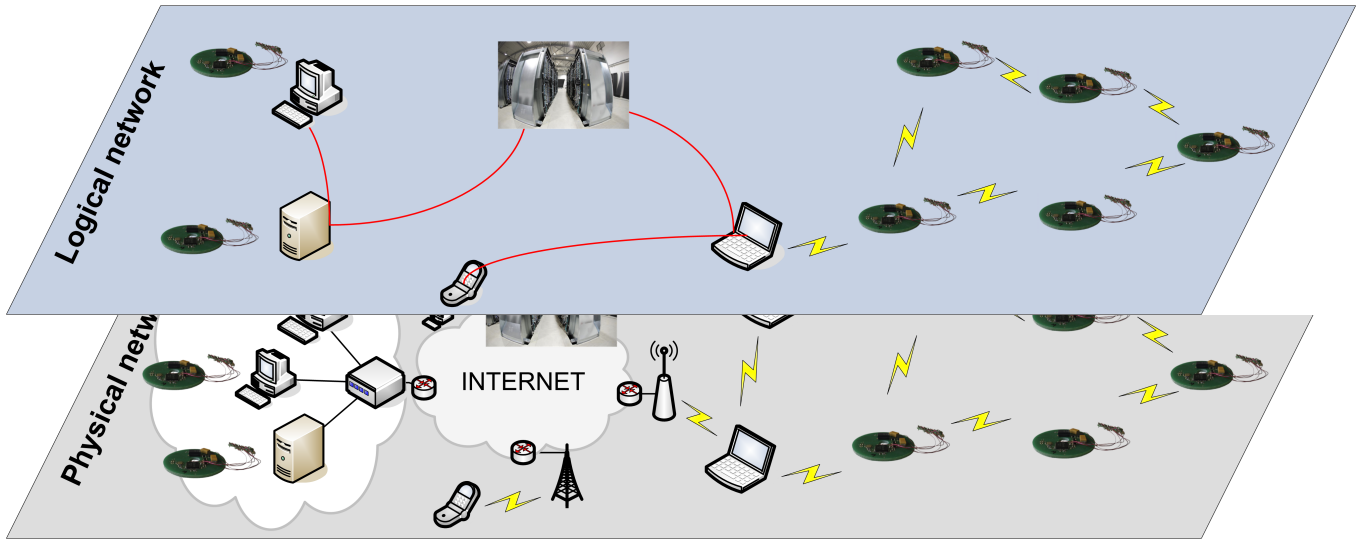
Solution requirements + approach 1/3

- **Requirement**: middleware for the secure and easy interconnection of a selected set of sensors, computers and cloud resources
  - **Approach**: secure and easy to manage virtual environment of all involved parties in a distributed and automatic fashion



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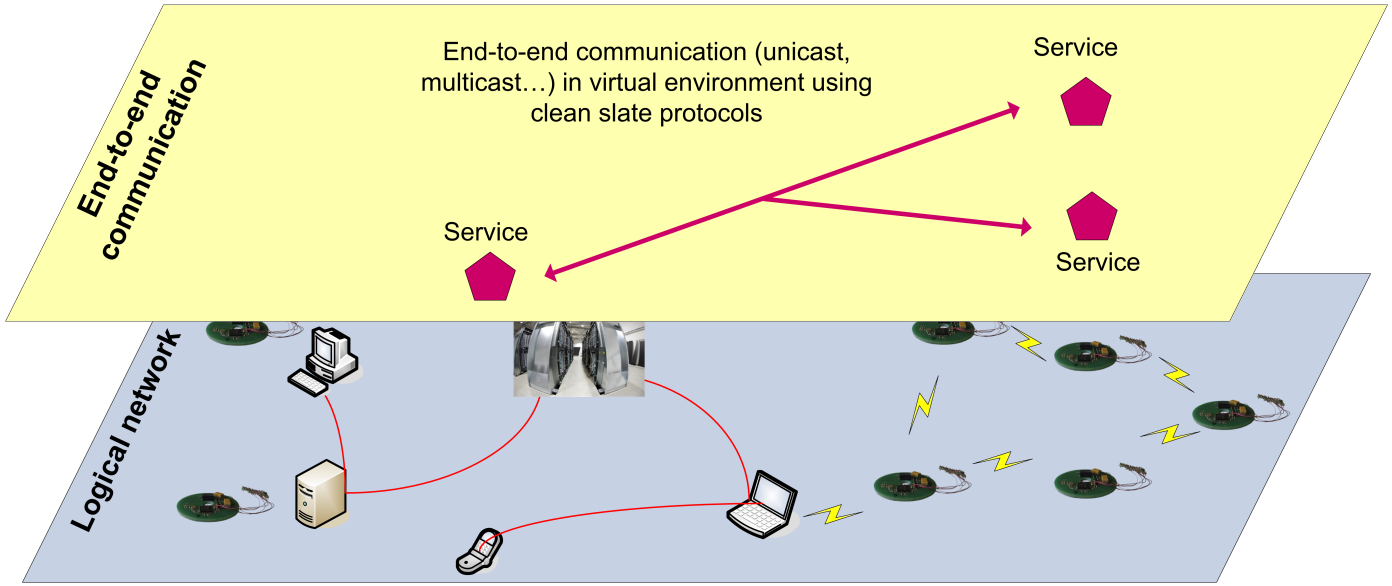
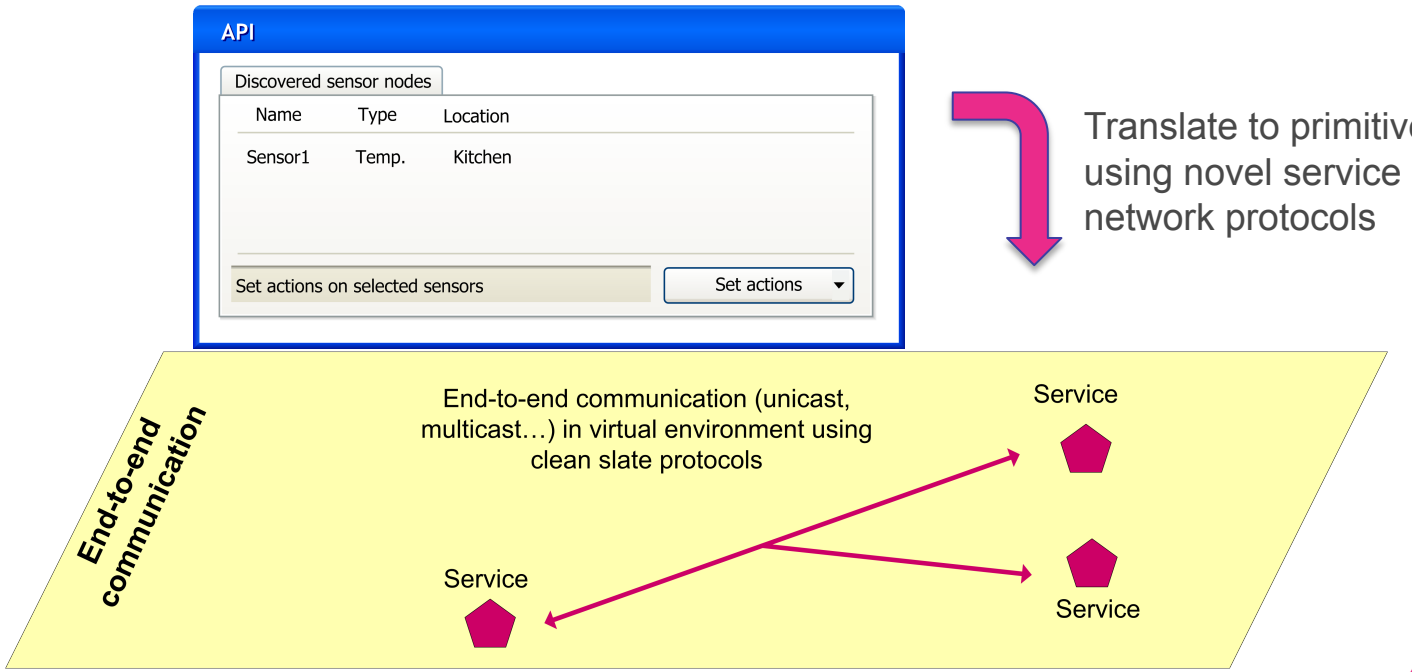
Solution requirements + approach 2/3

- **Requirement**: Easy and direct access to sensor data
  - **Approach**: Novel clean-slate end-to-end communication solutions within this virtual environment



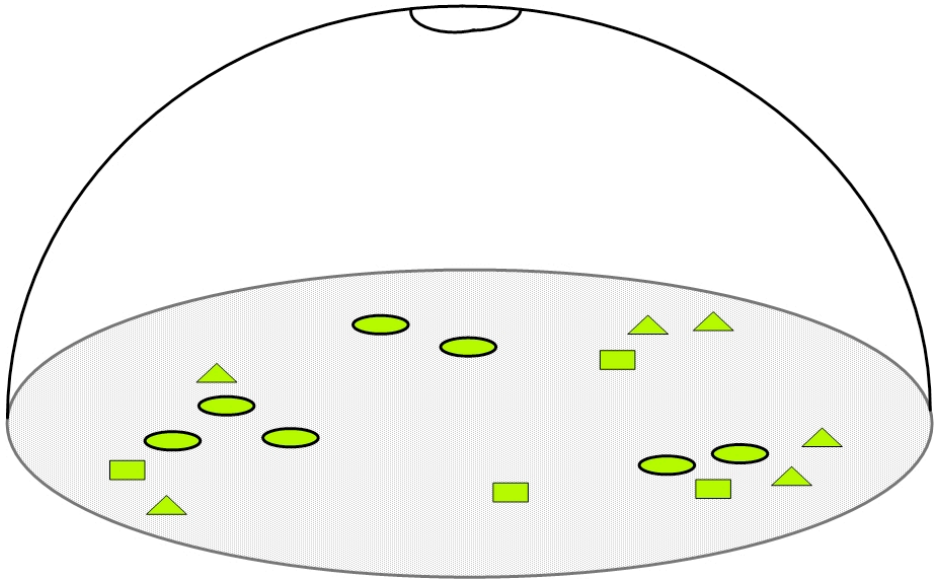
Solution requirements + approach 3/3

- **Requirement**: Help application developers to design applications and cloud services using the sensor data
  - **Approach**: New primitives for applications developers to discover and retrieve the sensor data they require



Generic MENO concept 1/2

- Managed ecosystems of networked objects (MENO)
  - **Definition**: a completely independent, managed, observable, virtual environment of interdependent, networked objects that cooperate in harmony



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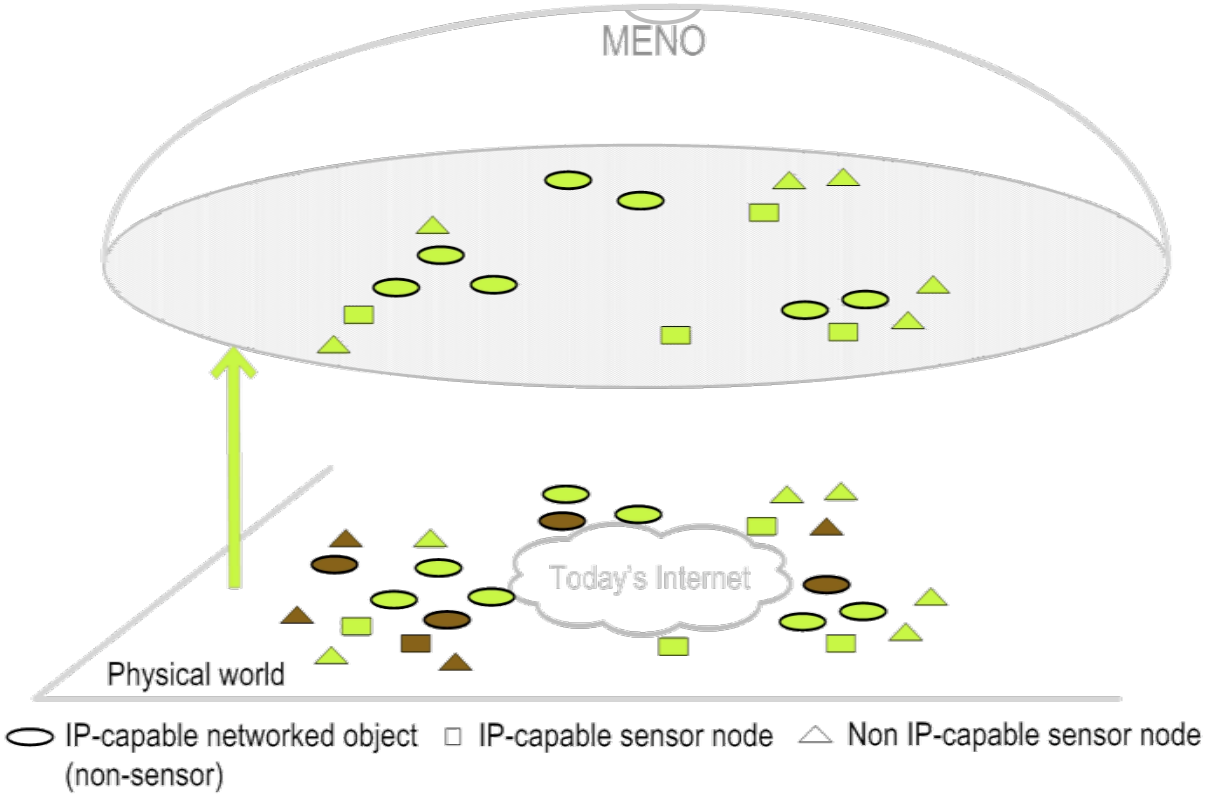
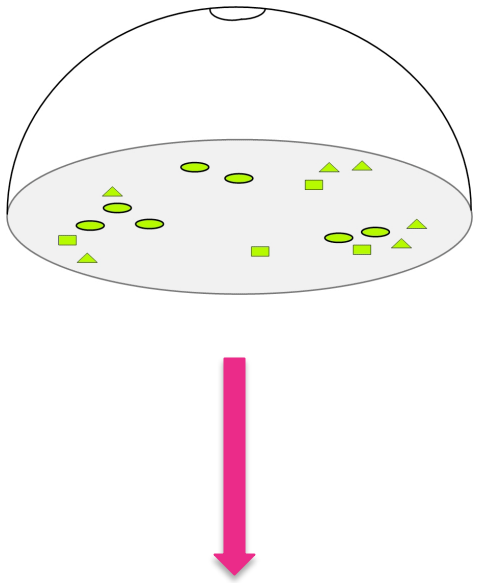


Generic MENO concept 2/2

- A completely independent, managed, observable, virtual environment of interdependent, networked objects that cooperate in harmony

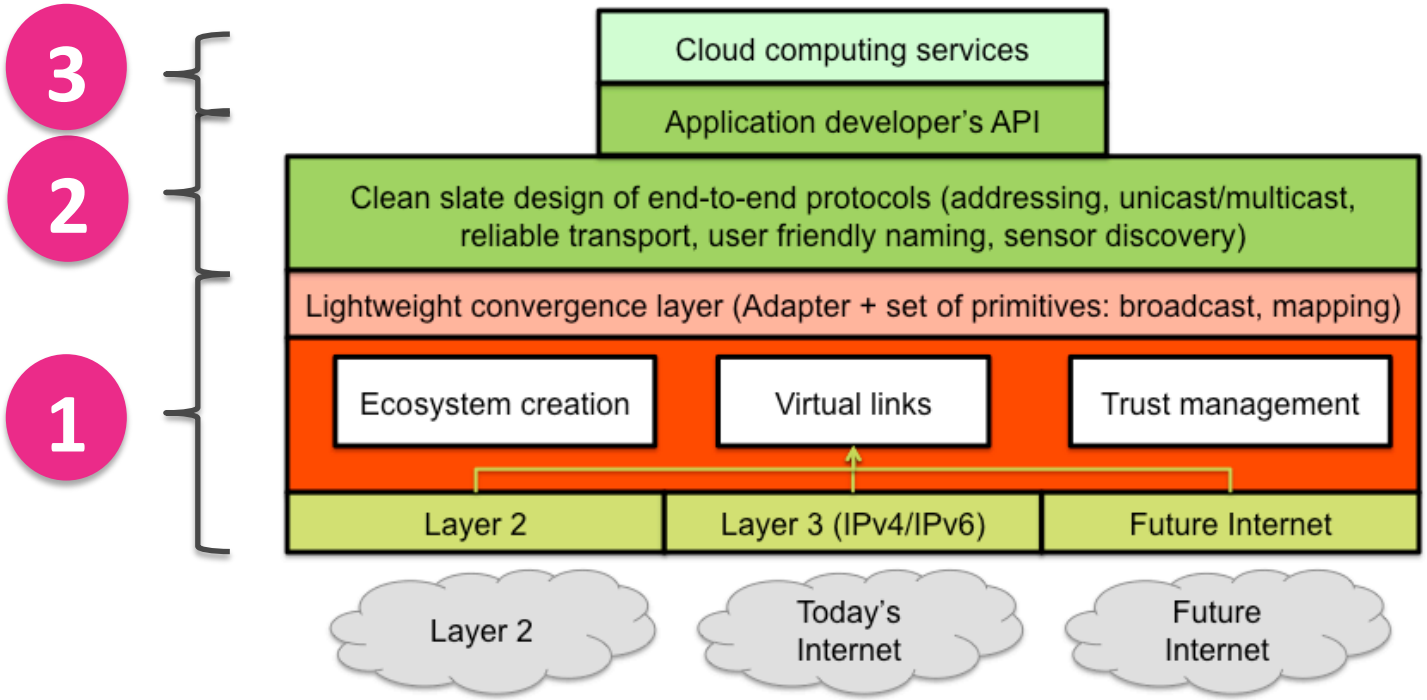


Direct mapping to use cases

- **Object**: any communicating entity, i.e. lightweight sensor nodes, PCs, virtual machines, cloud resource…
- **Interdependent**: objects rely on each other for common goal (see use cases)
- **In harmony**: self-* and end-to-end operation
- **Virtual environment**: one logical network, even if physically distributed
- **Completely independent**: shielded and secured
- **Managed**: flexible creation and control
- **Observable**: properties can be exposed to outside world

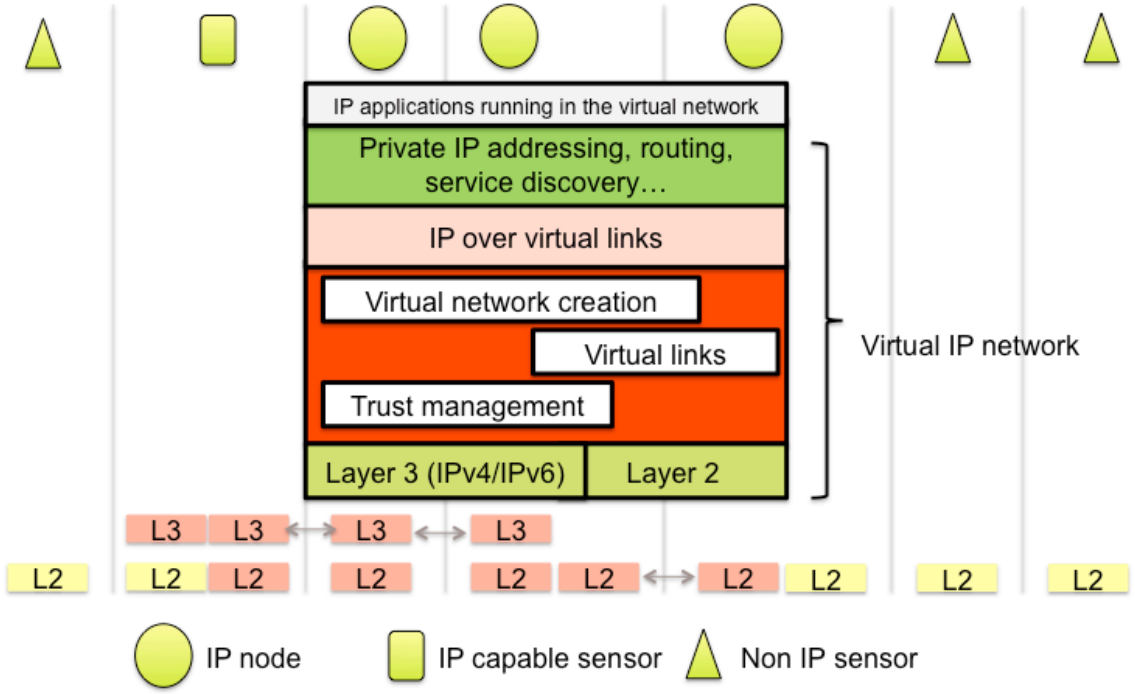
MENO objectives to realize

1. Creation and management of the virtual network
2. Development of novel clean-slate end-to-end solutions and API on top
3. Development of cloud computing services to realize use cases

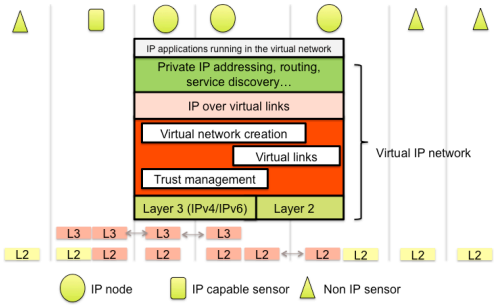


MENO objective 1

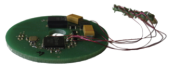
- **Current State-of-the-art:** virtual IP networks of distributed groups of devices or virtual machines on top of layer 2/ layer 3 networks

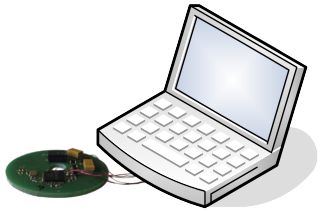


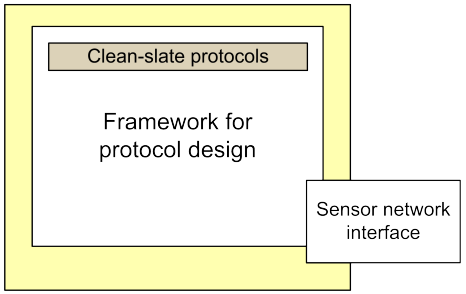
MENO objective 1

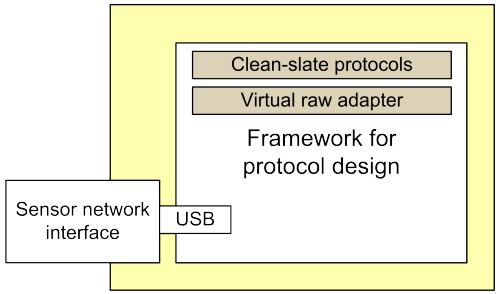


- **Next steps** to start realizing this objective
  - IP not possible on sensor devices ➔ allow clean slate design
    - ~~Virtual IP adapter~~ ➔ Virtual raw adapter: create your own packets/protocols directly interpretable by sensors
  - Interaction powerful devices and sensors
    - Sensor network interface in framework to design network protocols for PCs, laptops…



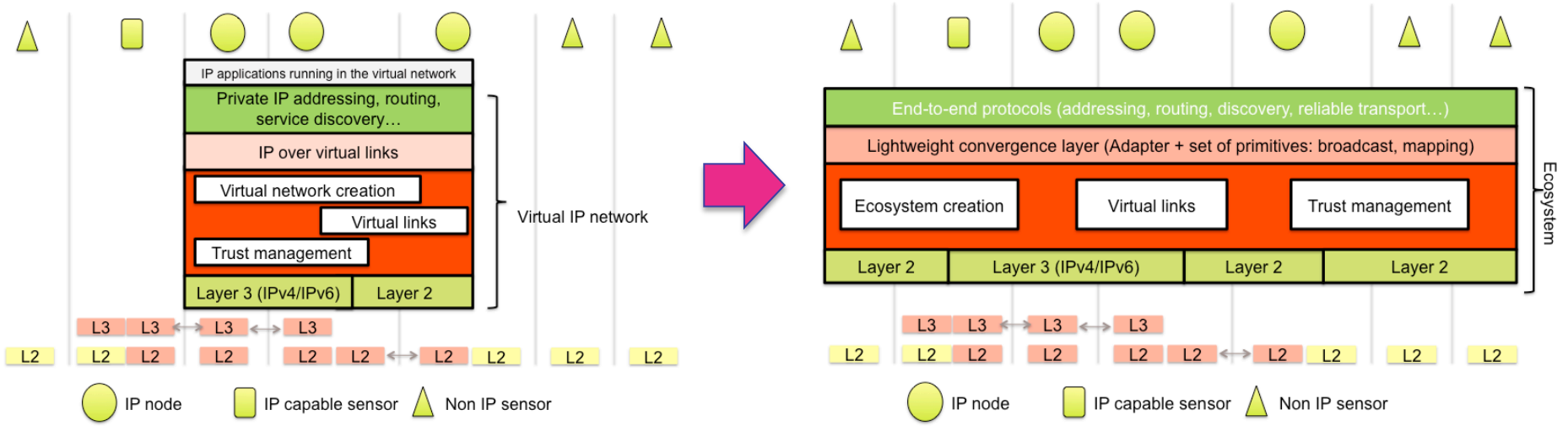






MENO objective 1

- Next steps
  - using protocol development framework, the virtualization layer will be extended to include sensor nodes



MENO objectives 2 and 3

- Design of **clean-slate end-to-end protocols** on top of the virtual network – requirements
  - Efficient and intelligent distribution of (sensor) data
    - Unicast and multicast support
    - Addressing scheme supporting multicast
      - E.g. cloud service collecting data from several sensor networks
  - Naming, discovery and a flexible API for application developers
    - User-friendly naming
    - Easy discovery of sensors and cloud services
      - As simple as in a LAN
    - API to easily design services, used by cloud
      - E.g. retrieve all data from the temperature every 10 minutes

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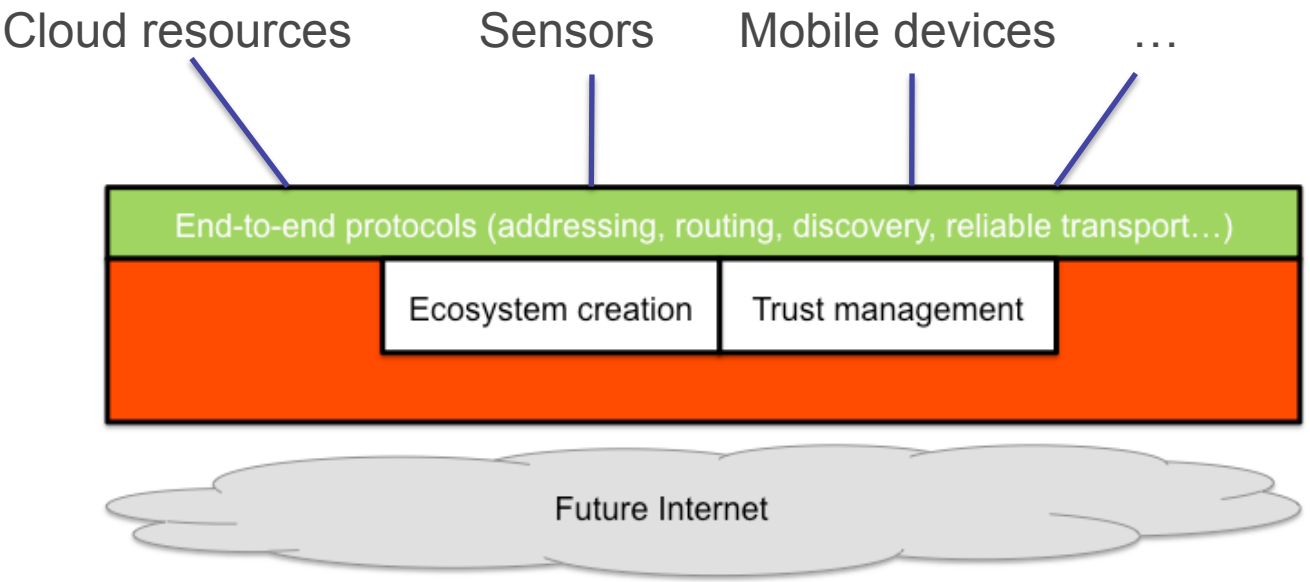
Ultimate idea

- Virtualization as part of Future Internet to support privacy, mobility, security… (Internet of things)
- Support innovative smart infrastructures and processes based on sensor networks, cloud like service infrastructures, wireless capabilities



Advantages 1/3

- Virtual environment creates an environment in which all participants can easily and directly communicate without bothering about security, connectivity, mobility…
  - Configure-plug-and-play integration of new sensors, computers, cloud resources matching the use case or communication needs (easy management)
  - Direct communication with different types of sensors without bothering about gateway APIs
  - Easy support for multiple sites
  - Built-in mobility support: moving virtual resources, moving sensors, migrating to another cloud provider…
    - Objects stay within the same virtual environment that will reorganize itself automatically
  - Secure: shielded from the outside world

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Advantages 2/3

- Direct sensor access within the virtual environment using clean-slate end-to-end protocols bypasses limitations of today's IP protocols
  - Have been designed with a completely different mindset
  - Not tailored to the characteristics of sensor devices and the corresponding traffic flows
  - End-to-end approach = seamless integration of sensors
    - Examples
      - End-to-end unicast/multicast
      - End-to-end sensor discovery and naming
  - Design optimized solution within a small world
    - Versus a generic solution for including sensors in the Future Internet (not as an add-on) ➔ would be extremely complex
    - Clean-slate in virtual environment offers a migration path

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Advantages 3/3

- New primitives for application developers
  - API can make use of novel end-to-end protocols
  - Use sensor data in an easy and natural way
  - Speed up design of services and applications (both on "normal" computing devices and in cloud)
  - Stimulate design of novel applications and services
- Integration of cloud resources
  - Benefit from processing and storage capabilities, without bothering about technical complexity
  - Create complex processing chains (using API)
  - Easily enrich the data and publish it to external parties
  - Deal with huge amounts of data (scalability)

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Conclusion

- The Internet becomes “sensorized”, so how to deal with these huge amounts of data?
- Outsource processing and storage to cloud
- Add-on gateway approach creates too many limitations (multiple vendors, multiple sites, mobility…)
- Novel approach with MENO concept
  - Create virtual environment
  - Design clean-slate protocols and new APIs
  - Easily create cloud services to set up processing chains
- MENO nicely maps to use cases
- …and at the same time introduces some challenging research problems

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Ingrid Moerman – ingrid.moerman@intec.ugent.be

Jeroen Hoebeke – jeroen.hoebeke@intec.ugent.be

Ghent University – IBBT
Department of Information Technology (INTEC)
INTEC Broadband Communication Networks (IBCN)
Gaston Crommenlaan 8 (Bus 201)
B-9050 Ghent, Belgium

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